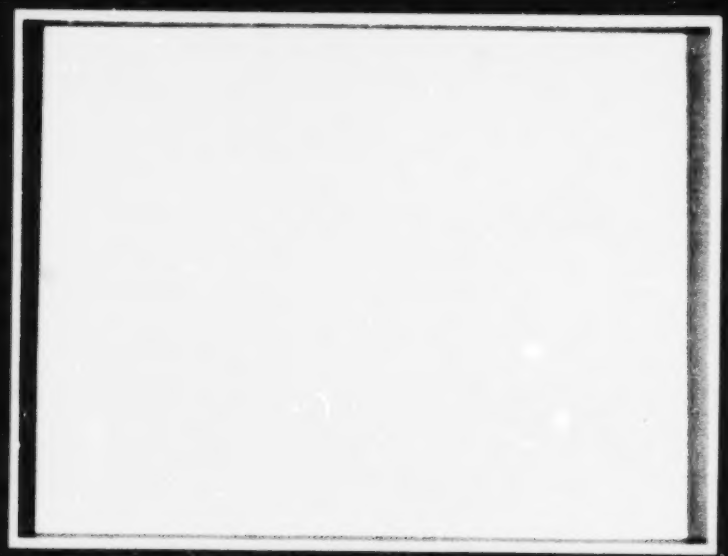


CREDA

Yukon 3

Residential Greenhouse

CREDA is a program which has been jointly funded by Energy, Mines and Resources, Canada and the Yukon Government, Department of Economic Development and Tourism. For more information or copies of reports contact the Energy and Mines Branch, Yukon Government, Box 2703, Whitehorse, Y1A 2C6.

Foreword

The availability of secure and affordable energy supplies is a subject of national concern. Our primary energy sources are becoming more costly and less accessible. However, Canada has both the resources and technical expertise needed to develop renewable and alernative sources of energy.

The government of Canada and Yukon have entered into a Conservation and Renewable Energy Demonstration Agreement as one means of pursuing this end. Cost shared by the territorial and federal governments, CREDA has a budget of $3.3 million and is dedicated to the development and demonstration of conservation and renewable energy technologies.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently;
- To develop broad public awareness of the potential of renewable energy and conservation technology;
- To provide opportunites for the commercial application of the technologies;
- To create economic spin-offs for manufacturing, industry and commerce;
- To create employment in new or existing energy-related industries.

The residential greenhouse which is reported on in the following pages is an important attempt to develop broad public awarenss of the thermally ameliorative characteristics of the properly conceived and constructed greenhouse addition. Particularly in remote locations where heating oil and fresh produce is expensive, greenhouse additions can have a significant impact on reducing fuel demand and contributing to the nutritive needs of residents.

EXECUTIVE SUMMARY

The following report examines the technical and economic viability of residential greenhouse additions in Whitehorse, Yukon. The greenhouse was constructed using the south facing wall of an existing residence as a common wall.

Construction costs for the greenhouse were approximately $200 per m^2 lower than the average residential construction costs, hence it can be argued that the payback on the project is immediate.

The greenhouse addition covered an area of 34 m^2 and was built with a full concrete basement. There are 4.5 m^2 of near vertical double glazing and an additional 4.5 m^2 of double glazing at an angle of 50^o facing south.

Total construction costs were $18,000, including proponent's labour. Annual fuel demand for the residence has been reduced by about 10 per cent for an annual saving of $425.

In addition, produce to the value of $1,000 is grown annually in the greenhouse for domestic consumption and commercial resale.

Typically the greenhouse operates for nine months each year. There is a net thermal loss during the months of November, December and January as a result of the large area of glazing.

The simple payback for the project is 12.5 years.

Résumé pour l'exécutif

Le rapport suivant examine la viabilité, du point de vue technique et économique, de l'addition d'une serre chaude à une résidence située à Whitehorse au Yukon. La serre en question a été construite en se servant du mur sud d'une résidence existante comme mur mi-toyen.

Les coûts de construction de la serre ont été moindres que les coûts de construction moyens d'une résidence par environ 200$ du mètre carré; de ce fait, on pourrait affirmer que dans le cas de ce projet, le retour sur l'investissement est immédiat.

La serre couvre une superficie de 34 m^2 et a été construite sur une surface en béton. Il y a 4.5 m^2 de double vitrage disposé presque verticalement et un autre 4.5 m^2 de double vitrage disposé à un angle de 60°et orienté vers le sud.

Le coût total de la construction s'est élevé à 18.000$, incluant les travaux effectués par le propriétaire de la résidence. La consommation annuelle de combustible de la résidence a été réduite d'environ 10%, ce qui représente une économie annuelle de 425$.

De plus, on fait pousser annuellement dans la serre des légumes pour une valeur de 1.000$ destinés à la consommation domestique et à la vente au détail.

Règle générale, la serre n'opère que neuf mois par année. En Novembre, Décembre et Janvier, il se produit une perte nette de chaleur à cause de la grande surface de vitrage.

Tout calculé, le retour sur l'investissement pour ce projet est de 12 ans et demie.

1. INTRODUCTION.....1

2. GENERAL DESCRIPTION OF PROJECT.....3

3. FUEL CONSUMPTION ESTIMATES.....5

4. PAYBACK ANALYSIS.....8

5. PRECONSTRUCTION DECISIONS.....9

6. DESIGN ALTERNATIVES.....15

7. OPERATION.....18

8. PERFORMANCE.....20

9. BUDGET SUMMARY.....21

10. CONCLUSIONS.....22

11. BIBLIOGRAPHY.....23

APPENDIX A COSTS AND CHARACTERISTICS OF GREENHOUSE GLAZZINGS

APPENDIX B TEMPERATURES AND HUMIDITY SUMMARIES

APPENDIX C PHOTOGRAPHS

This report gives details of the construction of a passive solar greenhouse/solarium addition to an existing residence. This project was funded under the CANADA/YUKON CREDA (Conservation and Renewable Energy Demonstration Agreement) with 30% of the materials and all of the labour being supplied by the homeowners, Wayne and Donna Wilkinson.

The project site is located in the subdivision of Riverdale in the City of Whitehorse, Yukon Territory. Whitehorse, 61 DEG. 43 MIN. North Latitude and 135 DEG. 04 MIN. west Longitude is the capital and largest city in the Territory. It is the central hub through which most material and human resources flow from and to the surrounding communities. In fact it was originally founded in 1901 as a communications and shipping centre at the terminus of the railway built following the gold rush of 1898.

Riverdale is located in the valley bottom across the Yukon River south of the Downtown area. It is surrounded on the east and south by hills and on the west by a high steep river bank. All of the valley bottom has been long known for wintertime temperature inversions which trap cold air in the valley bottom making local temperatures lower than the surrounding hills and causing ice fog. Of late the novelty of ice fog has shown a more sinister side as the same phenomena is shown to trap wood smoke from heating fires.

Much of Riverdale gets no direct sun during part of the winter as the low sun is blocked by the surrounding hills. The site where the house is located has an average solar exposure for Riverdale with some sun available on all days of the year, the amount dependent on atmospheric conditions and zenith of the sun. Grey mountain in an east-southeast direction limits the morning sun during the late fall to early spring months to a 10 AM rising.

The passive solar greenhouse/solarium reported on in the following pages is an attempt to develop public awareness of the potential of solar energy as a supplement to space heating using a demonstration house which is affected by conditions equalling or surpassing those faced by most houses in the Yukon.

The objectives as stated in the proposal were;

1. To demonstrate that significant fuel can be saved by the retrofit construction of a greenhouse/solarium to capture and use solar energy for heating.

2. To demonstrate that a significant contribution of high quality, high nutrient value vegetables can be made to the family food source.

3. To demonstrate that energy can be saved by the local production of food crops on a year round basis, as opposed to shipping in southern produce.

In January of 1981 construction began on the 35 square metre greenhouse attached to the existing 110 square metre house. The house is located on Lot 4, Block 244 Riverdale subdivision.

The addition is 4.3 metres deep and covers the full 8 metre width of the southerly wall of the house. At it's highest the roof of the greenhouse is 3.5 metres above the floor.

The greenhouse envelope has approximately 17 square metres of near horizontal glazing in the roof, 13 square metres of southeast facing vertical glazing and 4 square metres of southsouthwest facing vertical glazing. The east wall, half of the roof, one third of the west wall, and the bottom metre of all glazed wall surfaces are framed and insulated to reduce heat loss through the outer envelope of the greenhouse. The roof is insulated to Rsi 11. The walls are insulated to Rsi 6. The concrete foundation is insulated on the outside of the concrete to Rsi 6.2 with 76mm of polystyrene type VI rigid board insulation.

The solar addition is attached to the rear wall of the house. The east-southeast facing wall and roof which contain most of the glazed surface were built parallel to this wall. The glazing in the south west wall was located to capture what sun was available as it moved into the western sky before it disappeared behind the neighbouring house. These exposures, though not optimal for heat production, were compromises made between heat production, plant requirements and practical construction constraints.

Glass was chosen for the glazing medium. Though its light transfer properties are good it was chosen primarily to satisfy the requirements of the householders to maintain the view of the mountains to the east.

Thermal storage was provided by masonry exterior finishing, stucco of the existing house, the concrete foundation of the addition and the gravel and water components of the hydroponic growing system in the greenhouse.

The structure was closed to the weather before the first frosts of the fall of 1981. Due to a more sunny than usual, albeit cold fall, this first season for the partially planted beds was extended into mid December. Normally Yukon gardeners here must provide supplementary heating to extend the growing season past mid September.

Total construction costs were $13,000 not including the value of labour supplied by the homeowner or $371 per square metre of greenhouse floor area. If the cost of labour, valued at $5,000 is included the total construction costs become $18,000 or $514 per square metre.

This cost compares favourably with average Whitehorse building costs of $702.00 per square metre.

When the project began, the house was heated by an oil fired hydronic system. A wood boiler was later added to the system in series with the oil boiler so that the oil boiler would automatically come on if the wood boiler failed to maintain a pre set temperature of the heating fluid.

The before construction oil consumption averaged at 5400 l/annum.

Before and after construction consumption data is tabulated in TABLE, 3A where l is litres of #2 fuel oil and wood is mixed fire killed softwoods. The total of all heating energy sources has been converted to oil. To convert wood to oil a cord has been assumed to be equivilant to 540 l.

T A B L E 3 A

YEAR	WOOD	+ oil in l	= total oil equivilent in l
BEFORE CONSTRUCTION			
1980/81	2(est.)	3772(actual)	4852 l
1981/82	1(est.)	4193(actual)	4733 l
AFTER CONSTRUCTION			
1982/83	6(est.)	838(actual)	4078 l
1983/84	6(est.)	400(est.)	3640 l

These figures indicate an average annual oil equivalent saving of 934 litres per year. At present prices, $0.455/l, this savings would be worth $425.00.

These calculations do not include the value of heat consumed in heating the additional 680 cubic meters of building volume. This heat load has not been calculated because it is heated for use only on a seasonal basis and only by the sun. If the space were used as living space, rather than a greenhouse, and heated on a year round basis then there would be a heating load in this area and a need to consider the amount of solar that went to offsetting this load.

TABLE 3B is produced to simulate what the consumption would have been without the retrofit using actual degree day data for Whitehorse for the years after retrofit 1983 and 1984. Using actual degree day data may give a more accurate comparison of the before and after retrofit performance of the house because differences in climatic conditions between years will be taken into account.

For instance during the heating season of 1980/81 there were only 6915 heating degree days, however, 1982/83 was a much colder year with 7332 degree days.

The table shows the degree days for each of the heating seasons listed.

The energy consumed by the house for heating in oil equivilent litres (l) from TABLE 3A, is divided by the degree days to determine the number of litres consumed per degree day (l/DD).

To calculate the amount of oil that would have been consumed in years 82/83 and 83/84 had the retrofit not been done the l/DD for the two years before retrofit (80/81 and 81/82) were averaged and then multiplied by the degree days applicable to the year being projected. These figures are indicated as litres per year no solar (l/yr no solar).

To calculate the number of litres saved (l/yr savings) the consumption in column 1 is subtracted from l/yr no solar.

To convert the litres saved to dollars saved ($/yr savings) $0.445 has been used as the present value of a litre of oil.

T A B L E 3 B

YEAR	ACTUAL D D's	l	l/DD	l/yr no solar	l/yr savings	$/yr savings
80/81	6915	4852	.70			
81/82	7276	4733	.65			
82/83	7332	4078	.56	5000.00	419.51	940.95
83/84	6783	3640	.54	4578.52	427.02	946.65

By comparing TABLES 3A and 3B it can be shown that the savings projected in TABLE 3A closely track the savings calculated in TABLE 3B using degree days. Thus the savings projected would seem to be verified.

If only the value of the oil savings is considered a simple payback on the investment can be calculated as $13,000/425=30.6 years or $18,000/425=42.3 years if the cost of labour is included.

If an objective of construction is to provide a food growing facility then the value of the produce produced should be considered. During the summer of 1983 approximately 250 kgs of vegetable produce was grown for family consumption and sale. The value of this produce was $875. A further $125 worth of bedding plants were grown for family use and sale. The total value of production from the greenhouse therefore is $1000.

TABLE 4A summarizes the simple payback analyses for the greenhouse considering both oil savings and the value of produce.

T A B L E 4 A

MATERIAL COSTS	+ LABOUR COSTS	/ SAVINGS	= PAYBACK IN YEARS
PAYBACK BASED ON VALUE OF SOLAR HEAT ONLY			
13,000	000	425	30.6
13,000	5,000	425	42.3
PAYBACK BASED ON VALUE OF SOLAR HEAT AND PRODUCE			
13,000	000	1,425	9.1
13,000	5,000	1,425	12.6

It can be argued that the payback is less than zero years since in all cases the cost of construction was no more than average building cost. This of course only applies if one of the objectives of the project was the provision of additional living space.

Before construction began on the greenhouse several decisions had to be made which directly affected the design of the facility. Without careful consideration and exploration of the ramifactions of each of the following questions the facility could fail in part or in whole no matter how economic or efficient the design might be.

The needs and aspirations of the householder are paramount. If a solar addition and the requirements of the householder are not compatible then the solar aspect should be abandoned or reduced to an acceptable proportion. There is little advantage in building something that will be neither used nor appreciated. In the case of the Wilkinson greenhouse commitments were ranked as greenhouse first with solar heating a very close second.

What was the intended purpose of the facility? Was the space to be used for solar collection and heating only, primarily as a living space, or primarily for growing plants? If the space is to be used for the supply of heat only then the design would be radically different than if it was to be used for growing produce.

No matter what the function of the structure the basic elements of a solar collector must be provided. It must have: an inner absorbing,usually dark coloured, surface to convert the incoming light energy into heat energy, a thermal storage medium to store the excess heat during periods of high production for release during periods of low production, an outer transparent membrane to reduce heat loss through reradiation and convection to the great cold Yukon, and some means of transporting the heat energy produced into the house.

If the intended end use of the facility is only to provide heat then the simplest and cheapest form solar collector can be provided. This could consist of a simple shallow insulated box mounted either vertically or tilted facing in a southerly direction. The box could contain the storage medium or the heated air could pass through it on the way to the house.

The major difference between a solar heater and a greenhouse or solarium is the distance between the opaque energy converting surface and the transparent membrane. Whereas in a solar heater this distance is minimized to reduce heat loss and cost in a greenhouse or solarium it is maximized to make room for people and/or plants. It must be remembered that whenever this distance is increased several other aspects also increase;

*the surface area will increase,

* the potential exists to increase the collector surface,

* heat losses through the envelope will increase, therefore, the facility will require more of the heat being produced to heat itself with less available for export to the house, and

* construction costs will increase.

Each of these factors must be considered and balanced one against the other and against the needs of the homeowner. For example it would be of little use to build the addition 4 metres wide if the homeowner had an uncompromizing requirement for a room 4.5 metres wide.

Differences between a space meant for growing plants and one for living would mainly involve finishing materials and ease of access. Since mostly exotic plants are grown in greenhouses, temperature ranges and humidity requirements for these plants are roughly the same as for people. The need for thermal storage and the circulation of air to remove heat and introduce fresh air would remain the same for either end use.

To date in the demonstration greenhouse no attempt has been made to extend the season beyond that which the solar heating will support. The longest season has extended into early December and the shortest to mid October. The governing factor has been the availability of sun. When the sun failed to show for two or three days, coupled with cold temperatures the greenhouse froze. Consistently the beds have been thawed and the greenhouse is maintaining overnight temperatures adequate to sustain plant life by the end of February.

The season of use must be determined. If for example, it is to be used on a year round basis then some form of thermal shuttering should be considered for the months when there will be a net heat loss through the glazing. As use is extended into colder months the design temperature (difference between the inside and outside temperature) will increase and the amount of insulation should correspondingly increase. Similarly should the number of layers of glazing used, though shutters may be considered as a substitution for a third layer of glazing.

The area of greatest heat loss is through the glazing. A second layer of glazing can reduce this loss by 40 - 50%. A third layer will further reduce the loss by another 33%, while each layer only reduces the incoming radiation by 10 - 15%. Shutters can result in up to a 75% reduction, depending on R value but only if they are used.

Winter access from the exterior should be eliminated or at least controlled through a buffer zone such as an exterior vestibule.

The location of the existing house and other natural and man made obstacles surrounding the site must be considered when planning the addition. A due south exposure over a flat open lake is ideal but hard to come by. Any design work should be preceeded by investigation of shading patterns. The best way to accomplish this is to prepare a sun path drawing from the solarium location and to overlay any obstacles which may shade the glazed surfaces. The drawing should at a minimum be produced for the month in which the solarium will be expected to operate with the lowest sun angles. This is the condition in which the longest shadows will be produced. It is also a good idea at this time to check local by-laws to find out what conditions might exist if construction, tree planting or other activities were to start which might hinder your solar access. Sun path charts should be developed to explore the effect of all legal scenarios.

It is important that the solar space be attached to the house, as was the case with the demonstration house. Placing the greenhouse and house on either side of a common wall will limit heat loss, reduce construction costs and improve access.

Access has been a continuing problem with the demonstration greenhouse. The original design called for entry from the exterior through a vestibule. The exterior entry without any interior entry proved unsatisfactory. Because of changing usage patterns of the house it has not been possible to establish a permanent interior entrance to the greenhouse. This has served to show how even minor annoyances can cause a great deal of dissatisfaction with a project.

The period of use of the solar addition will determine the orientation and tilt of the glazing. Due south, as mentioned is the optimal orientation however any deviation up to 30 degrees can be tolerated and as has been shown by the demonstration project 57 degrees can work reasonably well. The angle of tilt of the glazed surface should be within 15 degrees of perpendicular to the zenith of the sun on the shortest day that the facility is expected to provide heat. That is, if the addition is expected to provide heat from March to September and the sun is 30 degrees above the horizon in these months then the optimum angle of the glazing would be 60 degrees. Placing the glazed surface at any angle between 45 and 75 degrees above horizontal would be acceptable.

The demonstration greenhouse's vertical glazing was set at 75 degrees from horizontal. This is within tolerance for December sun at 60 degrees north latitude which is 5 degrees above the horizontal. At angles this close to vertical it may be better to simply construct a vertical wall. It would be cheaper to design and require less skilled labour to build. In this particular design however it would have caused the roof to be longer. Thus the insulated part of the roof would have to be made longer. This would have deepened the shaded area in back of the greenhouse. Since this was a prime growing area for plants requiring high light intensity the compromise was made and the wall was slanted.

The type of glazing used will be determined by the requirements of the householder and the performance requirements of the design. The Wilkinson's chose glass because they wanted to maintain the view of the mountains that was only visible from the rear of the house. Other materials such as fiberglass, UV-stabalized poly, PVC, and other plastic sheets or honeycomb pannels have been used in Yukon greenhouses. Each has its own specific characteristics and design requirements.

Presented in APPENDIX A is a reprint of TABLE 1 and TABLE 2 from the "Journal of Agricultural Engineers. The prices of materials listed in TABLE 1 are in 1958 dollars however they can be used for comparison purposes as the ratios have stayed about the same. Also presented is "TABLE 3" from "Hobby Greenhouses in Alberta", which gives a comprehensive description of the characteristics of common glazing materials.

During sunny days between mid February and Mid October the Demonstration Greenhouse produces more energy than it requires to sustain the internal environment for plants. The first strategy for dealing with the excess is to put it into storage in the greenhouse itself. There are three storage materials and three different stages of storage. The first stage is used to shave the peaks off fast rises or falls in temperature. This is accomplished by using the stucco and cement parging which covers the entire north wall of the greenhouse. Because the material is thin, 20mm, it does not have a large capacity for storage but because of the large area it can react quickly to sharp rises or falls in temperature. This surface accounts for approximately 0.6 cubic metres of storage.

The second stage consists of 1.8 cubic metres of gravel used as the growing medium for the hydroponics. This system soaks up the more long term energy surpluses.

Lastly 7 cubic metres of water which bathe the beds removing heat for deep storage. This water, the hydroponic nutrient solution, is recirculated to the beds twice during the night at which time the heat is returned to the greenhouse.

These three systems combine to provide storage for excess heat produced during sunny periods then return the heat to the greenhouse during periods when production is lower than losses

Heat flows from the greenhouse to the house through openable windows located high in the common wall. Cold air returns through openable windows located low in the common wall. This system does a satisfactory job of moving the heat into the house, however, the natural pattern of flow did not fit the life patterns of the house occupants. Heat was required in the front part of the basement by 9:00 o'clock in the morning where a playschool was operated. Heat is often available from the greenhouse at this time but it is being delivered to the upper rear part of the house. Since the house heating system is hydronic it could not practically be used to distribute any of the heat from the greenhouse.

Designs decisions should therefore take into account the use patterns of the building to determine if natural circulation will provide heat where and when it is needed or if supplementary forced circulation is required.

Another problem which was not foreseen before construction was that one of the occupants of the house would develop asthma. The development of this condition had nothing to do with the construction of the greenhouse, however, the elevated humidity levels resulting from circulation of greenhouse air in the house aggravated the symptoms. This focuses on the need to check that any allergies and sensitivities of the occupants or users of the space will not be adversely affected.

Excessive humidity levels only become a problem with the demonstration greenhouse during late summer, and then only under specific conditions. With the greenhouse full of well developed plants transpiration is at a high level. If the overnight temperature has been low and the house has been allowed to cool severe condensation can occur on wall and ceiling surfaces if warm greenhouse air with a relative humidity above 60% is allowed to enter the house. To combat this problem greenhouse air is vented to the exterior in the morning for about an hour or until the humidity drops below 60% before being introduced into the house.

From the experience gained in the demonstration project some suggestions of design alternatives can be made that will reduce the cost of similar structures and that may improve their operation.

Though glass was the only choice suitable for this greenhouse other people may be willing to trade off the high solar and visual transparency of this material for a less expensive one. The total glass cost was $2,500.00 with a handsome discount being provided by the supplier because of the quantity. A reasonable substitution could be made using a plastic material for about $500.00 including additional material for framing to support the more flexible material. This would result in a price reduction of about $2,000.00 without seriously reducing the solar penetration.

The original conceptual drawings of the greenhouse included a 300mm thick concrete floor containing pipes through which hot greenhouse air would be circulated. This system was to be part of the heat storage system. The consultants hired to review the design suggested that the heat storage capabilities of the concrete would be enhanced if there was more surface are such as if it formed the foundation.

This was an excellent suggestion. As it turned out the amount of concrete required for the slab was exactly the amount required to pour a complete basement. Thus a full basement was added with a small additional expenditure for forming materials, all of which were recycled into the greenhouse construction.

The concrete foundation has not been actively used as part of the storage regime because there is sufficient capacity in the system without it. The value of the foundation was quoted by one contractor as $5,000.00. If a standard 100mm thick concrete slab floor with 75 mm of extruded polystyrene insulation under the slab were substituted the expected savings would be $4,000.00.

Because condensation problems were predicted for the greenhouse preserved wood was used in all framing materials in the walls. Condensation has not been a problem and this additional cost could have been eliminated. The resulting saving is estimated to be $100.00.

Exterior walls were constructed of 2 x 6 material to accommodate the thickness of insulation used. New techniques such as the Yukon curtain wall system or a double wall system would allow construction using standard 2 x 4 studs. It is doubtful however if any of these systems would have much of an impact on the price of construction as they would lead to increased wall thicknesses and increased insulation. This of course would have it's benefits in improving the function of a solarium.

Reductions could be made in size which would result in savings in both labour and material. The experience with this greenhouse is that if anything it could be larger. There's just no space for impractical human endevours such as growing mangos.

TABLE 6A tabulates the suggested areas for cost reductions.

T A B L E 6 A

SUBSTITUTE GLAZING MATERIAL	2000.00
ELIMINATE CONCRETE FOUNDATION	4000.00
DELETE PWF MATERIAL	100.00
TOTAL REDUCTION	$6100.00

Using the estimated reduction a revised payback analysis can be calculated as follows in TABLE 6B.

T A B L E 6 B

MATERIAL COSTS + LABOUR COSTS / SAVINGS = PAYBACK IN YEARS

PAYBACK BASED ON VALUE OF SOLAR HEAT ONLY

6,900	000	425	16.2
6,900	5,000	425	28.0

PAYBACK BASED ON VALUE OF SOLAR HEAT AND PRODUCE

6,900	000	1,425	4.8
6,900	5,000	1,425	8.4

Using the new projected construction cost of $6,900 not including the value of contributed labour the construction costs per square metre would be $197.00. If the value of labour is included construction would cost $340 per square metre. This is about half the cost of average Whitehorse residential building costs.

During sunny days between mid February and Mid October the Demonstration Greenhouse produces more energy than it requires to sustain the internal environment for plants. The first strategy for dealing with the excess is to put it into storage in the greenhouse itself. There are three different stages of storage and three different storage materials.

The first stage is used to shave the peaks off fast rises or falls in temperature. This is accomplished by using the stucco and cement parging which covers the entire north wall of the greenhouse. Because the material is thin, 20mm it does not have a large capacity for storage but because of the large area it can react quickly to sharp rises or falls in temperature. This surface accounts for approximately 0.6 cubic metres of storage.

The second stage consists of 1.8 cubic metres of gravel used as the growing medium for the hydroponics. This system soaks up the more long term energy surpluses.

Lastly 7 cubic metres of water bathe the beds removing heat for deep storage. This water, the hydroponic nutrient solution, is recirculated to the beds twice during the night at which time the heat is returned to the greenhouse.

These three systems combine to provide storage for excess heat produced during sunny periods then return the heat to the greenhouse during periods when production is lower than losses

Heat flows from the greenhouse to the house through openable windows located high in the common wall. The warmed air enters the rear first floor area and moves toward the front of the house cooling as it goes. As it cools it settles to the floor and drifts down the stair well to the basement. Cold air is drawn into the greenhouse from the basement to replace the exiting warm air through openable windows located low in the common wall.

An unanticipated benefit of the greenhouse has been its ability to drive a natural air conditioning system during hot days. Because the house is heated hydronically there is no forced air system to move cool basement air into the upstairs parts of the house to cool it during hot days. By reversing the action of the greenhouse it is possible to draw cool basement air up the stair well. This is accomplished by closing the windows from the basement, opening the upper windows and opening the roof vent in the greenhouse. Air is now drawn from the first floor of the house into the greenhouse and exhausted through the vent in the roof of the greenhouse. Basement air is drawn up the stairs to replace the air drawn into the greenhouse.

Excessive humidity levels only become a problem with the demonstration greenhouse during late summer, and then only under specific conditions. With the greenhouse full of well developed plants transpiration is at a high level. If the overnight temperature has been low and the house has been allowed to cool severe condensation can occur on wall and ceiling surfaces if warm greenhouse air with a relative humidity above 60% is allowed to enter the house. To combat this problem greenhouse air is vented to the exterior in the morning for about an hour or until the relative humidity in the greenhuse drops below 60% before being introduced into the house.

To maintain the aspect of demonstrating the potential of solar heating by means of greenhouse/solarium addition no attempt has been made to extend the growing season in the greenhouse beyond that which the solar heating will support. The longest season has extended from the first of March into early December and the shortest to mid October. The governing factor has been availability of sun. When the sun failed to show for two or three days coupled with cold temperatures the greenhouse froze. Consistently the beds have been thawed and the greenhouse is maintaining overnight temperatures adequate to sustain plant life by the middle of March.

During 1983 and 1984 a strip recorder was installed in the greenhouse to record temperature and humidity levels. Information collected on the strip charts is compiled and submitted as APPENDIX B in a spread sheet format giving daily highs and lows, weekly highs and lows, as well as weekly averages.

The spread sheet is further summarized in the form of two bar charts; one for weekly average temperature and one for weekly average relative humidity.

The budget for the Wilkinson solar greenhouse is as follows;

Material	$13,000.00
Labour	$ 5,000.00
Total	$18,000.00
Creda Contribution (2/3 material)	$ 8,710.00
Homeowner contribution (1/3 material)	$ 4,290.00
Homeowner contribution (labour)	$ 5,000.00
Total	$18,000.00

Solaria and greenhouses can provide a substantial contribution to the energy required to heat a house. The contribution is greatest where there is a long heating season. In Whitehorse some heating is required in every month of the year. This greenhouse was successful because it was designed to reduce the heat load on the house in all months and to completely eliminate the need for other sources of heat during the months of April to October.

Designs must be suited to the life style and living patterns of the householders. Human operational input should be kept to a minimum. The more gadgets to operate or things to open or close the harder it will be for the occupants to operate them efficiently. Though interactivity with the solar system is enjoyable and educational the novelty wears off after a few years. If manually operated equipment is installed initially the design and financial plan should provide for phasing in of automatic equipment.

Solaria can be built at costs comparable to average building costs. Therefore, solar heating can be achieved without additional cost when incorporated into any expansion designs for a new house.

Solar additions can be used as greenhouses. As well as suppimenting the heating supply they can provide additional cash crops which can be used to offset the cost of construction. Humidity problems can arise but generally are minimal. What problems do arise can be dealt with by exhausting high humidity air. One system which has ben considered for the greenhouse is to use a standard residential heat pump to remove excess moisture and to pump heat into the house. This would have a secondary benefit of excluding the need to circulate greenhouse air through the house. Thus any allergenic reactions to the greenhouse air would be prevented.

GREENHOUSES IN ALASKA, University of Alaska, Fairbanks, Alaska.

HOBBY GREENHOUSES IN ALBERTA, Alberta Agriculture, Edmonton Alberta.

PASSIVE SOLAR HEATING IN CANADA, Report ER79-6, EMR, Ottawa, Ontario. K1A 0E4

PERFORMANCE OF SOLAR GREENHOUSES, John Martin, Monica Sloan, Nova Corporation, Calgary, Alberta. T2P 2N6

SOLAR ENERGY, Energy Services Division, B.C. Hydro, Vancouver, B.C. V6Z 1Y3

SOLAR GREENHOUSING, Ecology House, Toronto, Ontario. M5R 2S1

SOLAR SYSTEMS IN B.C., Energy Conservation Division, B.C. Hydro, Vancouver, B.C. V6Z 1Y3

THE DEVELOPMENT AND TESTING OF AN ENVIRONMENTALLY DESIGNED GREENHOUSE FOR COLDER REGIONS, Lawand, Alward, Saulnier and Brunet, Macdonald College of McGill University, Quebec Canada. H9X 1C0

Appendix I

Costs and Characteristics of
of Greenhouse Glazings

TABLE I

PLASTIC GREENEOUSE COVERINGS

TYPE	THICKNESS	LIFE	COST/M^2 *
Glass	3mm	Indefinite	55
Polyethylene	1-8 mil	1-2 years	1-2
UV-inhibitor		2-4 years	2-3
Polyvinyl chlorid	4-6 mil	1-2 years	3-10
UV-inhibitor sheet	8-12 mil	4+ years	6-20
rigid	corrugated	10+ years	12-15
Polyester (MYLAR)	3-5	7+ years	12-14
Rigid fiberglass	4-8 1200-2400	0-20 years	22-47

*cents/ft^2 1958

**grams/m^2

TABLE 2

LIGHT AND HEAT TRANSMISSION CHARACTERISTICS

OF

GREENHOUSE COVERINGS

FILM	THICKNESS IN MILS	VISIBLE LIGHT TRANSMISSION PERCENTAGE	UV	TRANSPARENCY TO INFRARED
Glass	125	90	NO	NO
Polyethylene	2	87	YES	YES
Polyvinyl chlorid	13	87	SLIGHT	NO
Polyvinyl	3	88	YES	SLIGHT
Polyester	4	88	NO	SLIGHT
Fiberglass (clear)	125	80-90	SLIGHT	MEDIUM
Water	2	96	YES	NO

reprinted and metrified from:

JOURNAL OF AGRICULTURAL ENGINEERS 3(4); 281-287,1958

TABLE 3. Description of Greenhouse Coverings

COVERING	PHYSICAL DATA[4]	RADIATION TRANSMISSION[1] (%)	DURABILITY[3]	MAINTENANCE	COMMENTS[2]
GLASS	Strength: Single (SSB) 2 mm Double (DSB) 3 mm Triple (TSB) 5 mm Sizes: 400 x 600 mm 500 x 500 mm 500 x 750 mm or custom	90 (4.4) 75 (0.9) — (direct light)	Until broken	Glass panels must be recaulked every few years. Regular washing with detergent, or oxalic acid, needed.	— commonly called window glass — breaks easily, especially when older — heavy — 9-11% light loss when dirty — tempered glass is 2-3 times stronger, however more expensive. It also comes "frosted" or "hammered" for better light diffusion. Use of larger pane sizes is possible, but requires special structural members to give water and air tight construction. — available in Alberta — numerous suppliers.
FILM PLASTICS A. Regular Polyethylene	Mil thickness: 1,2,4,5,8,10 91.4 cm — 12.2 m wide 15.24 — 30.48 rolls (3 to 40 ft wide) (50 to 100 ft long rolls)	85-88 (88) depending on thickness (diffused light)	9-12 months	Must be kept stretched tight or inflated for maximum strength. Needs frequent cleaning with mild detergent.	— not recommended for greenhouse use owing to very short life span — condensation problems — has a tendency to split on the fold — available in Alberta — 1,2,3,9,10,11,12,13,14
B. UV Treated Polyethylene	Mil thickness: 1,2,4,5,8,10 3' to 40' wide 50' to 100' rolls	85-88 (77) depending on thickness (diffused light)	1-2 years	Must be kept clean to increase winter light	— has been treated to make it resistant to ultraviolet light which causes regular polyethylene to break down rapidly. — use of at least 4 mil recommended, 6 mil preferable — useful as a second layer to reduce heat loss — prevents air leakage which causes higher humidity and condensation problems — available in Alberta — 1,2,5
C. Co-polymer films e.g., Monsanto 602	Mil thickness: 4,8 10' to 40' wide 100' to 150' rolls	85-88 (71) (diffused light)	2 years	Must be kept clean with mild detergent	— made of a blend of two resins, ethylene and vinyl acetate — tear strength twice that of regular polyethylene so has a slightly longer life — condensation problems — available in Alberta —1

COVERING	PHYSICAL DATA[4]	RADIATION TRANSMISSION[1] (%)	DURABILITY[2]	MAINTENANCE	COMMENTS[2]
D. Reinforced Polyethylene	Mil thickness: 8 (3 ply) 10' to 40' wide 100' and 150' rolls	85 (75) (diffused light)	2 year	Must be kept clean with mild detergent	— A polyethylene resin with a 2-3 cm glass or acrylic fiber mesh added for strength. Don't confuse with woven polyethylene which has a much lower light transmission. — condensation problems — usually hail proof — sewn to size for larger sheets — available in Alberta — 1,3,4,14
E. Reinforced Ultra Violet Treated Polyethylene (e.g., Monarfol-Ultra)		85	slightly longer than 2 years	Must be kept clean with mild detergent	— as above — available in Alberta — 18
F. Vinyl Films	Mil thickness: 4 to 12 8 mil most popular 7' to 40' wide 200' rolls	89-91 (91) (direct or diffuse light)	1-2 years	Needs frequent cleaning with mild detergent	— the 4 mil thickness is clear, 8 mil is hazy — must be heat-seamed together by manufacturer for widths greater than 5-7'. — not readily available in Alberta — surface electrostatic charge resulting in dust attraction.
G. Polyvinyl fluoride films	Mil thickness: 4 to 12 6' wide 50 to 100' rolls	92 (33)	7-8 years		— the best known polyvinyl fluoride film available is "Tedlar" made by Du Pont Co. — an excellent film but is too costly to compete with existing films. — used as a surface coating on fibreglass to improve weathering ability.
RIGID PLASTICS A. Polyvinyl-chloride (PVC)	Available in corrugated, ribbed or flat forms in various sizes	88-90 (transparent panels) 77 (translucent) (0)	2-4 years (untreated) 5-7 years (treated)		— available in UV treated and untreated forms — the untreated material darkens when weathered by ultra-violet radiation and heat within 2-4 years and thus is no longer recommended as a greenhouse cover. — UV treated PVC available in Alberta — 18 — very flexible material — installation must allow for large thermal expansion and contraction.

COVERING	PHYSICAL DATA[4]	RADIATION TRANSMISSION[1] (%)	DURABILITY[2]	MAINTENANCE	COMMENTS[3]
B. Clear acrylic (e.g., Plexiglass, Perspex, Transpex)	Mil thickness: 8	90-95 (0.8) (diffused light)	20 years	Clean as needed with mild detergent	— the "acrylic" most often used is polymethyl methylacrylate — highly resistant to impact — must be treated with an antistatic compound — installation must allow for large thermal expansion and contraction — half as heavy as glass — available with a ultra-violet resistant coating — sensitive to some solvents — very expensive — flexible — expands and contracts greatly and should not be directly nailed down. — Plexiglass easily scratched, however, scratch resistant 'Lucite' now available — available in double walled panels with an insulated air trap to reduce heat loss by up to 40% (e.g. Rohaglas — SDP with 83% light transmission) — available in Alberta — 3,8,19,20,21,22,23,24
C. Fiberglass	A basic polyester resin reinforced 75-90 (0.5) with glass fibers. Rated by weight (diffused light) per sq. ft: 4 to 8 oz widths up to 4' coverage Lengths up to about 24' (pre-cut), longer lengths on special order. Available in corrugated, or ribbed or flat forms. Ultra-violet treated.	10 year untreated 15-20 years "Tedlar" coated		Low maintenance. Should be kept clean and coated with clear acrylic-polyester resin as needed (approx. every 4-5 years)	— untreated form can yellow with time so that light transmission decreases each year. — purchase the ultra-violet treated form so that yellowing is reduced. — ultra-violet treatment is achieved by lamination with the polyvinyl fluoride film "Tedlar" — 2-4 times more resistant to impact and loading than glass. "Crazing" (not shattering) usually results from impact — if not kept clean, can get "blooming" or exposure of fibers due to surface erosion. — condensation problems — "Tedlar" coating can also reduce "blooming" — flammable; non-flammable forms available, however more expensive. — 15% acrylic additive has proven more durable than straight polyester formulations — available in Alberta — 1,5,6,7,9,11,12,13,15,16,17 — much lighter than glass so fewer supports needed.

1. Number outside parentheses refers to visible light transmission at 0.6 μ. Number in parentheses refers to thermal radiation transmission (% heat loss) in the range 5-25 μ.
2. For the key to Alberta suppliers and for sources of supply outside Alberta see Appendix 3.
3. Estimates of product lifespan are approximations only.
4. Common sizes of products given. Can often be purchased in smaller sizes. (.025 mm = 1 mil).

Appendix II

Temperature and
Humidity Summaries

SUMMARY STRIP CHART RECORDINGS DATE: 85.01.04

SPEECH-CUISE: LAWRENCE & DONNA WILKINSON

7 HETCH RD, WHITEHORSE, YUKON, Y1A FILE: STRPCHRT.CAL

DURATION: 83.06.01 TO 84.05.31

DATE	WEEKLY TEMP H	L	AV	HUMIDITY H	L	AV	DAILY TEMPERATURE H	L	H	L	H	L	H	L	H	L	H	L	H	L
1984																				
01.02	-5	-17	-11	96	83	89	-8	-9	-5	-8	-5	-17	-9	-12	-12	-15	-15	-17	-11	-17
01.09	1	-9	-6	92	60	86	-8	-9	-5	-8	-5	-7							3	-5
01.16	-9	-19	-14	95	80	85	-9	-12	-9	-19	-11	-19	-10	-16	-12	-15	-10	-19	-13	-16
01.23	15	-9	-1	90	45	70	2	-9	1	-9	12	-9	15	-7						
02.06	-1	-11	-7	90	68	76					-1	-10	-5	-10	-7	-11	-3	-10	-3	-9
02.13	22	-7	4	92	40	65	8	-7	15	-7	18	-7	8	-6	15	-2	22	-6		
02.20	25	-9	7	90	38	59	22	-2	25	-6	18	-9	25	-6	24	-9	21	-9	16	-9
02.27	33	-3	11	78	35	60	25	-3	15	-7	30	-3	33	0	23	2	9	1	30	2
03.05	35	1	18	80	35	60	33	1	12	6	32	6	35	6	35	5	35	7	29	9
03.12	33	1	12	80	30	64	12	6	14	9	32	1	12	8	33	1	28	9	15	4
03.19	33	5	15	75	38	61	18	5	25	5	33	6			15	10	17	12	20	12
03.26	50	6	21	75	33	55	15	6	34	8	32	9	32	8	40	8	50	9	40	6
04.02	50	9	22	75	35	51	30	7	50	9	43	6	40	5	33	3	33	2	40	8
04.09	43	4	22	85	28	54	38	4	35	5	43	5								
04.23	50	8	29	85	30	55			43	9	44	9	50	13	48	13	45	12	48	11
04.30	43	7	27	85	33	60	43	9	46	8	44	8	48	7	47	10	40	11	45	9
05.09	50	1	25	92	30	61	40	1	39	11	50	10	36	15	38	12	42	12	45	12
05.15	50	8	25	92	28	62	43	9	48	10	50	1	44	12	42	13	36	8	28	12
05.22	48	9	26	91	30	51	31	12	41	13	42	8								

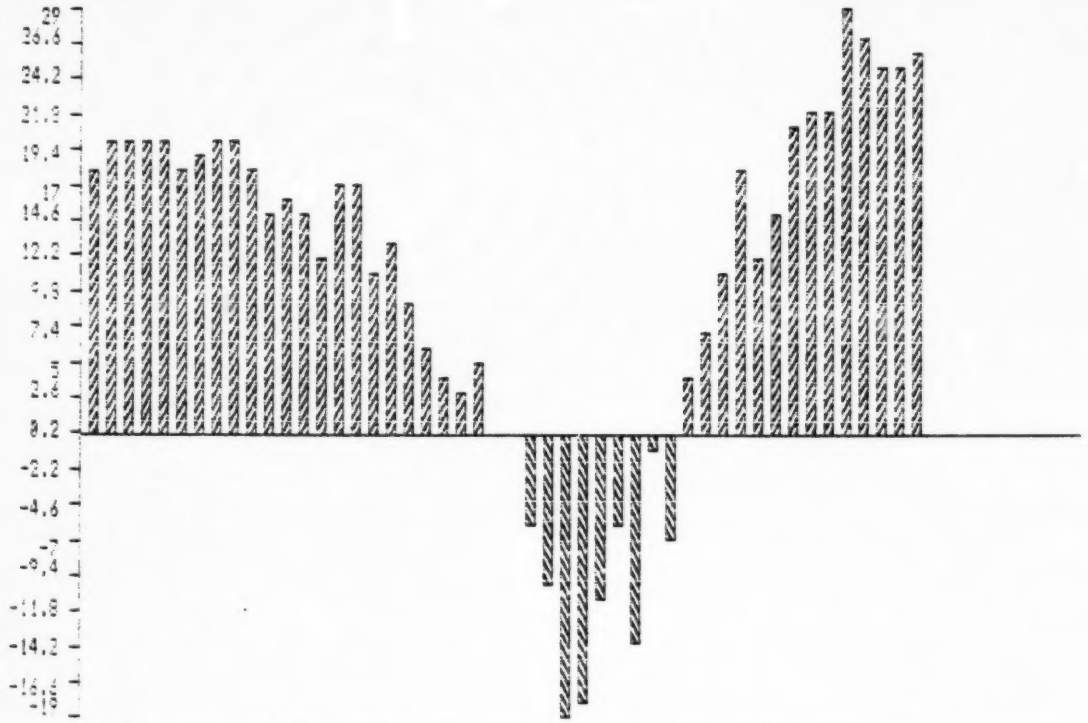
DATE	HUMIDITY L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
1984																				
01.02	95	95	95	96	85	96	85	88	83	85	83	83	80	90						
01.09	90	92	90	92	90	90													60	80
01.16	83	88	85	88	82	88	85	88	84	85	80	90	80	85						
01.23	73	80	75	80	50	75	45	85												
02.06					68	78	78	78	78	78	78	78	78	80						
02.13	73	81	45	82	40	80	55	80	45	80	35	78								
02.20	40	75	38	80	45	80	88	80	38	75	40	75	40	75						
02.27	40	78	50	78	35	76	25	75	45	75	60	75	85	78						
03.05	35	75	65	78	40	82	88	80	85	81	85	78	45	75						
03.12	75	78	68	85	80	80	58	70	88	78	58	78	55	75						
03.19	45	80	40	78	40	70	88	71	40	78	55	78	50	75						
03.26	45	78	50	75	80	78	58	72	88	72	85	78	80	68						
04.02	35	75	26	65	28	72	26	68	45	78	80	75	28	75						
04.09	32	75	31	75	28	85														
04.23	50	80	30	85	85	75	80	75	80	75	85	78	80	75						
04.30	45	80	35	85	40	85	88	80	88	75	88	85	85	80						
05.09	80	80	35	86	25	85	40	82	45	80	82	78	40	82						
05.15	40	82	30	80	38	80	28	82	82	82	86	82	50	82						
05.22	45	80	38	9	38	81														

SUMMARY STRIP CHART RECORDINGS DATE: 85.01.04
GREENHOUSE: WAYNE & DONNA WILKINSON
7 KETZA RD, WHITEHORSE, YUKON. Y1A FILE: STRPCHRT.CAL
DURATION: 83.06.01 TO 84.05.31

DATE	WEEKLY TEMP H	L	AV	HUMIDITY H	L	AV	DAILY TEMPERATURE H	L	H	L	H	L	H	L	H	L	H	L	H	L	HUMIDITY L	H	L	H	L	H	L	H	L	H	L	H	L	H
1983																																			
06.01	38	6	18	96	30	61					25	13	25	7	38	7	30	6	22	11					40	73	45	95	33	96	30	95	33	96
06.06	39	6	20	94	30	63	22	9	30	8	35	7	39	8	32	9	34	9	27	6	47	93	35	85	23	94	25	85	43	96	32	92	40	90
06.12	40	8	20	90	33	58	21	10	31	8	31	9	40	9	28	9	29	9	33	10	38	58	23	90	40	75	30	90	33	90	40	30	40	86
06.20	35	9	20	92	24	59	21	12	28	11	30	10	29	10	35	11	34	9	33	12	52	87	34	99	28	92	26	90	30	71	36	70	33	79
06.28	32	11	20	97	32	68	32	12	32	12	28	12	32	12	32	12	23	11	20	11	35	85	33	90	48	90	40	92	33	97	50	96	65	92
07.04	33	6	18	96	25	65			12	10	32	9	32	10	33	6	30	7	23	8			70	91	36	96	25	93	30	95	50	70	50	88
07.11	35	7	19	96	23	66	35	8	16	10	26	8	28	10	35	7	33	9	33	11	23	91	60	85	45	95	50	85	50	96			30	30
07.18	34	7	20	96	18	59	34	7	34	10	32	7	21	8	37	9	28	7	30	9	22	80	38	86	22	96	35	85	30	94	18	96	28	92
07.25	35	6	20	96	24	56	35	6	32	7	33	7									23	80	33	70	35	96								
08.02	38	8	18	97	30	64			38	8	22	9	32	5	24	7	27	6	32	7			30	90	50	89	33	95	50	75	44	84	40	90
08.07	35	5	15	97	55	71	20	8	25	7	19	9	23	5							55	75	50	95	60	97	40	93						
08.14	36	3	16	95	33	71	19	6			31	6	24	3	36	6	30	6	22	7	65	90			33	95	55	93	35	93	40	95	60	93
08.21	41	3	15	97	30	74	20	6	19	7	22	7	19	5	17	5	39	3	41	4	65	85	75	95	45	90	55	88	75	95	43	94	29	97
08.29	35	2	12	97	33	67	34	7	14	7	14	7	35	6	12	5	11	3	5	2	33	90	40	8	75	95	55	95	65	95	6	96	85	96
09.05	41	-2	17	95	28	60			25	-2	41	0	30	0	34	2	34	1	34	1			32	96	30	96	30	65	33	95	35	92	35	93
09.12	36	-1	17	95	36	69	36	7	33	2	35	5	25	3	20	3	30	2	31	-1	60	87	36	93	42	88	55	90	63	93	36	95	38	90
09.19	32	-2	11	90	38	66	5	3	10	3	21	11	22	4	24	9	32	2	4	-2	65	95	70	90	48	85	53	90	48	88	38	89	68	88
09.26	39	-6	13	93	38	71	16	1	31	-6	35	-4	36	-1	10	4	39	4	13	5	70	90	40	90	40	85	40	85	78	96	40	90	76	90
10.05	32	-6	9	90	35	70	11	1	8	1	23	2	32	-6							70	93	42	90	36	89								
10.11	22	-4	6	90	48	75			6	1	7	0	22	-1	8	0	19	-2	19	-4			70	90	70	86	46	90	84	89	68	85	50	83
10.17	13	-1	4	93	50	66	10	1	5	-1	7	-1	9	-1	4	0	12	-1	13	-1													90	50	85	50
10.24	13	-3	3	93	50	79	1	-1	3	-1	5	-2					11	-1	13	-3	88	93	85	93	85	93	70	93	55	90	65	90	70	85
10.31	23	-4	5	93	50	83	10	-1	3	-2	23	-4									89	93	85	93	48	92								
11.07	11	-5	2	89	63	79	1	-3	5	-4	3	-3	-1	-4	2	-2	11	-5	9	-5	70	78	63	90	75	83	85	93	38	88	75	86	70	86
11.14	10	-9	0	83	65	73	5	-6	7	-9	8	-7	10	-7							65	80	60	88	70	80								
11.21	3	-12	-6	88	75	83	3	-7	-3	-7	-5	-7	-5	-6	-5	-7	-5	-10	-7	-12	75	80	75	95	80	85	83	88	83	98	90	85	80	88
11.28	8	-22	-10	88	30	79	-7	-8	-6	-10	-7	-10	8	-21	-20	-22	-20	-22	-12	19	85	88	84	93	90	85	25	83	90	83	90	80	83	88
12.07	-18	-21	-19	60	83	77	-20	-21			-10	-21	-19	-21							80	93			60	83	70	85						
12.25	-7	-23	-18	90	75	77	-19	-20	-19	-20	-20	-22	-21	-22	-20	-23	-11	-20	-7	-12	75	77	75	76	76	77	75	76	75	76	76	80	80	90

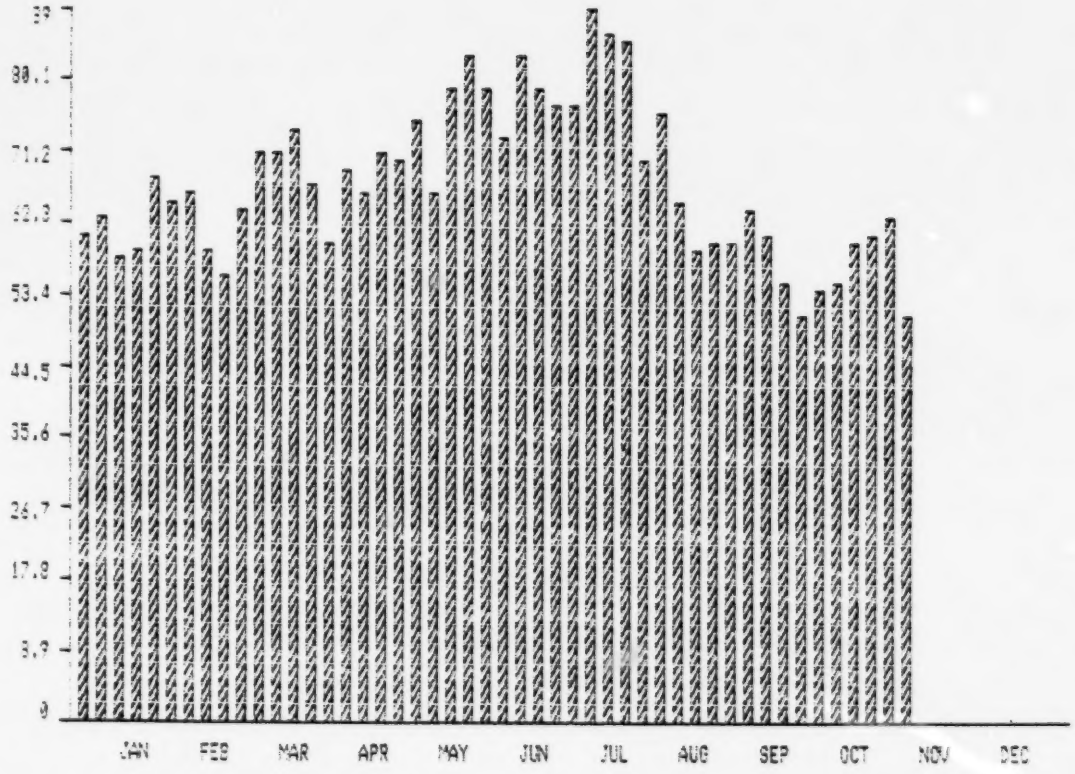
BAR CHART SUMMARY OF STRIP CHART RECORDINGS DATE: 95.01.04
GREEN-OLSEN WAYNE & DONNA WILKINSON
7 KETZA RD, WHITEHORSE, YUKON, Y1A FILE: STRPCHRT.CAL
DURATION: 93.06.01 TO 94.05.31

WEEKLY AVERAGE TEMPERATURE



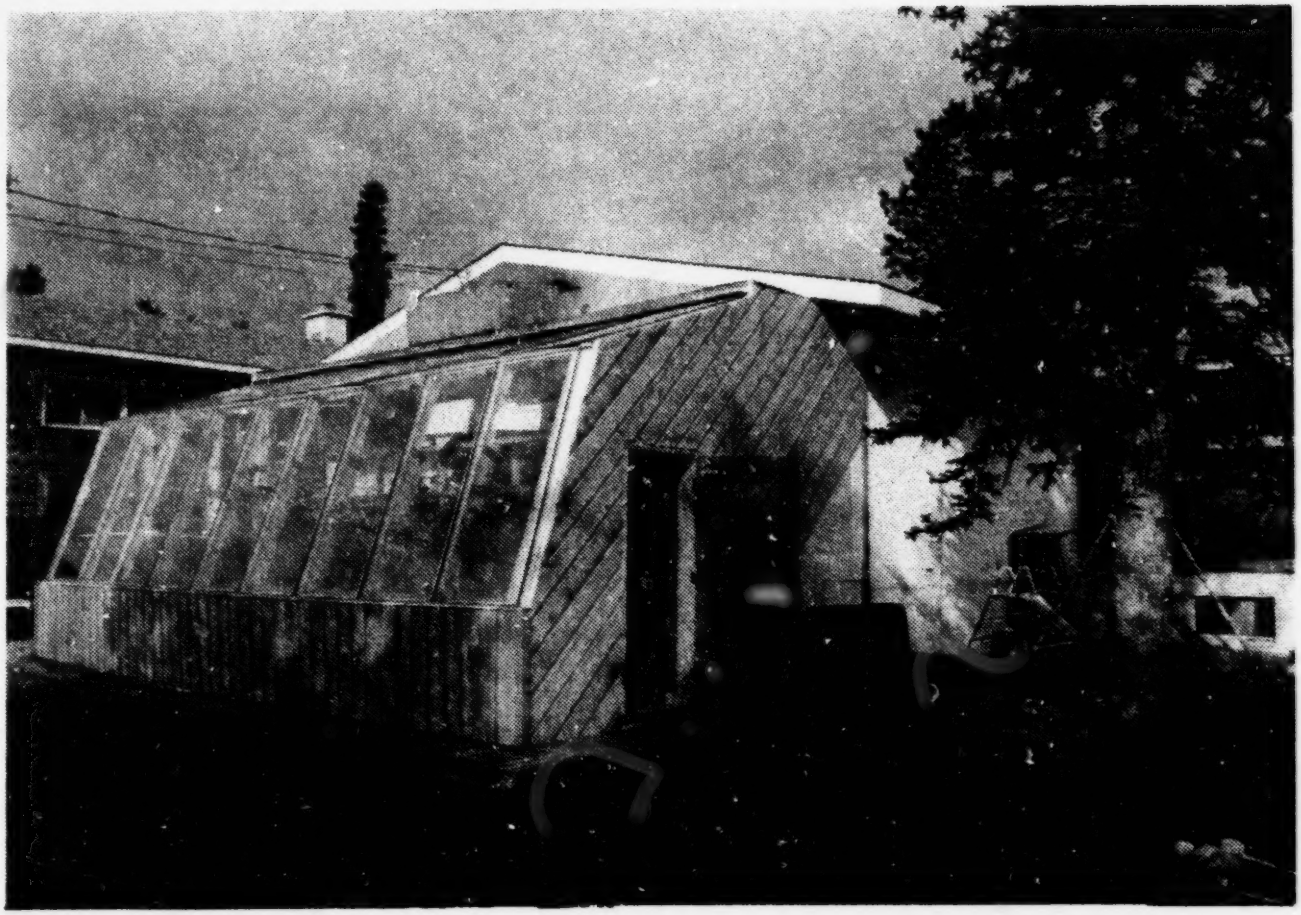
BAR CHART SUMMARY OF STRIP CHART RECORDINGS DATE: 85.01.04
GREENHOUSE; WAYNE & DONNA WILKINSON
7 KETZA RD, WHITEHORSE, YUKON. Y1A FILE: STRPCHRT.CAL
DURATION; 83.06.01 TO 84.05.31

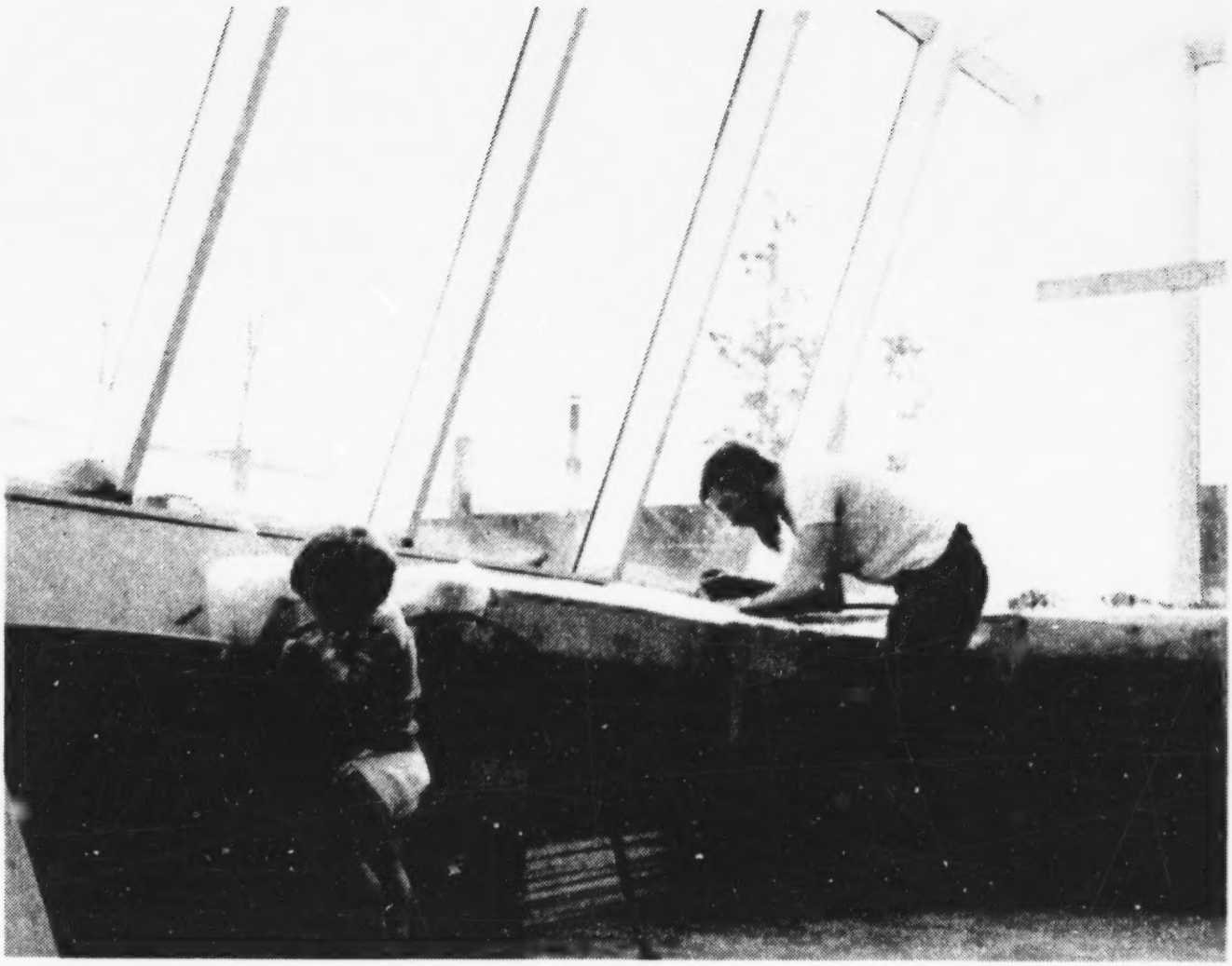
WEEKLY AVERAGE RELATIVE HUMIDITY

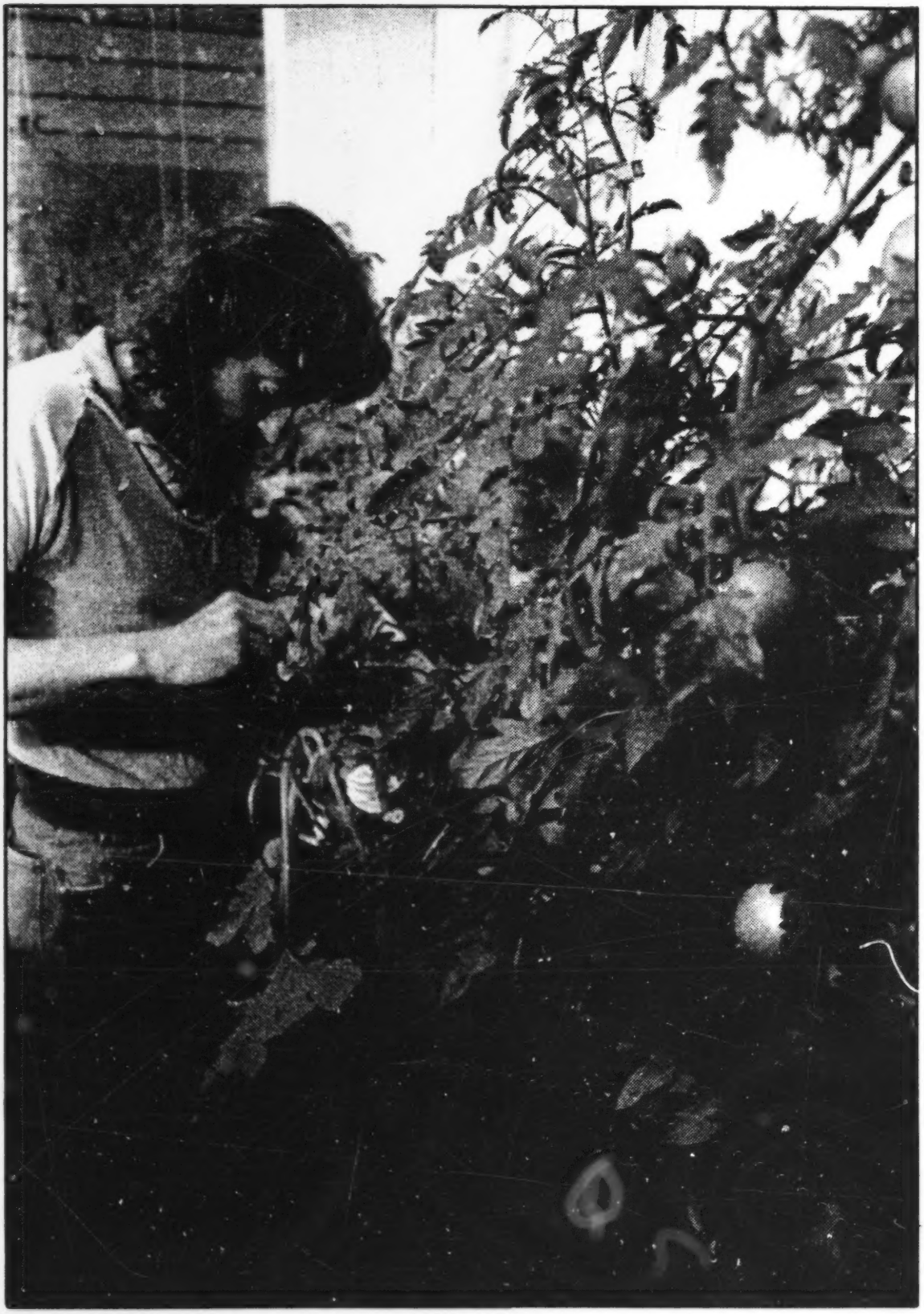


Appendix III

Photographs







Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

Yukon
Department of Economic Development and Tourism

RESIDENTIAL GREENHOUSE

Final Project Summary

Canada/Yukon Conservation and Renewable Energy Demonstration Program

Project No.
3766-4-3

Date:
February, 1985

Sectors:
Residential
Commercial

Project Locations:
Whitehorse

Technology:
Solar

Jurisdiction:
Yukon

Project Manager:
Robert E. Collins

Status:
Complete

Simple Payback:
12.5 years

Purpose:

1. Space heating of existing home.
2. Vegetable production for home use and commercial sale.
3. Additional living space.

Description:

A 34 m² solar addition to a suburban residence. Space is used to house hydroponic growing area and heat is stored for residential use.

Contributors:

Proponent	$9,800
Canada/Yukon	8,200
	$18,000

Demonstrated Benefits:

1. Reduction of heating-fuel demand of 10%.
2. 14% increase in living area
3. Annual produce valued at $1,000 (1984 dollars).

Further Information

Wayne Wilkinson
7 Ketza Road
Whitehorse, Yukon
Y1A 3V3
(403) 66704933

Economic Analysis:

Reduction in annual fuel demand/area of 20 per cent. Simple payback has been calculated by summing the economic benefits of fuel savings ($425) and grown produce ($1,000) and dividing into the project's construciton costs.

Information Transfer:

A final report has been prepared with details of the construciton, finances, problems and monitoring data. Copies are available by wirting to:

Energy and Mines Branch
Government of Yukon
P.O. Box 2703
Whitehorse, Yukon
Y1A 2C6
(403) 667-5384